MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

ETN4086 – MOBILE AND SATELLITE COMMUNICATIONS
(TE, MCE)

13 OCTOBER 2018
09.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTION TO STUDENT

1. This examination paper consists of **11 pages** (including the cover page) with **4 questions only.**
2. Each question is worth **25 marks. Attempt ALL questions.**
3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.
4. There is an **appendix** of useful charts, constants and formulae at the end of this question paper.

Question 1

(a) Cellular radio systems rely on an intelligent allocation and reuse of channels throughout a coverage region.

(i) With the aid of a diagram, describe the concept of frequency reuse or frequency planning.

[3 marks]

(ii) Describe the effect of hexagon geometry on cluster size.

[2 marks]

(iii) Explain the concept of frequency reuse factor.

[2 marks]

(b) Given that KK City, a metropolitan area in Malaysia, has an area of 1,500 square kilometres and is going to be covered by a cellular system employing a 7-cell reuse pattern. The Malaysian Commision on Multimedia and Communications (MCMC) has allocated to KK City 50 MHz of spectrum with a full duplex channel bandwidth of 75 kHz, with each cell having a radius of 5 kilometres. The offered traffic per user is 0.03 Erlangs and the Grade of Service (GOS) is specified to be of 2% for an Erlang B system.

You have been assigned by Teltom, a cellular service provider in Malaysia to design the suitable cellular network for KK City by computing the following:

(i) The number of cells in the service area.
(ii) The number of channels per cell.
(iii) Traffic intensity of each cell.
(iv) The maximum carried traffic.
(v) The total number of users that can be served for 2% GOS.
(vi) The number of mobiles per channel.
(vii) The theoretical maximum number of users that could be served at one time by the system.
[Hint: The area of a cell (hexagon) can be shown to be $2.5981R^2$ where R is the radius of the cell]

[2 + 2 + 2 + 2 + 2 + 2 + 2 = 14 marks]

(c) A cellular system using hexagonal cells, covers an area of $1560 km^2$ with a 12-cell reuse pattern. Each cell radius is 5km and cell area is approximated by $2.6R^2$ km^2. A total bandwidth of 25MHz is allocated to each cell of the cellular system. Each channel bandwidth is 200kHz. Each channel has 8 time slots and one time slot is allocated to one user. Each user uses an average of 0.05 Erlang with Grade of Service (GOS) of 2%. One control time slot is required per cell.

Calculate the number of subscribers that can be served by the cellular system.

[4 marks]

Continued...

Question 2

(a)

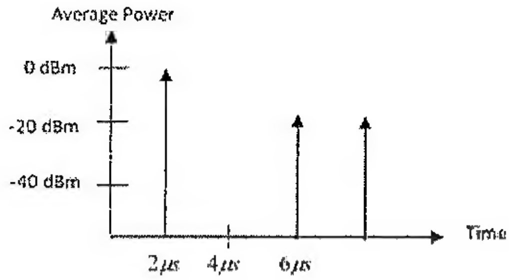

Figure Q2.1

Figure Q2.1 is the power delay profile of a type of channel fading.

(i) Identify the type of channel fading shown in the Figure Q2.1.

[1 mark]

(ii) Briefly describe the relationship between the coherence bandwidth and channel bandwidth for the type of fading in (a) (i).

[2 marks]

(b)

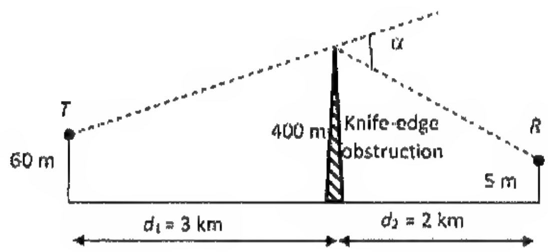

Figure Q2.2

A 900MHz carrier frequency is obstructed by a knife-edge obstruction shown in Figure Q2.2. Calculate the diffraction loss (in dB).

Hint: The Fresnel-Kirchoff diffraction parameter is given as $v = \alpha\sqrt{\frac{2d_1 d_2}{\lambda(d_1 + d_2)}}$

Diffraction gain, G_d (dB), can be found using:

$$G_d(\text{dB}) = \begin{cases} 0, & v \le -1 \\ 20\log_{10}(0.5 - 0.62v), & -1 \le v \le 0 \\ 20\log_{10}(0.5\exp(-0.95v)), & 0 \le v \le 1 \\ 20\log_{10}\left(0.4 - \sqrt{0.1184 - (0.38 - 0.1v)^2}\right), & 1 \le v \le 2.4 \\ 20\log_{10}\left(\frac{0.225}{v}\right), & v > 2.4 \end{cases}$$

[10 marks]

Continued...

(c) Sixam is a cellular provider that has been given a license to operate Third Generation (3G) cellular service in Malaysia. The company is planning to set-up a transmitter that will produce 40 W of power, and is applied to a unity gain antenna with a 2100 MHz carrier frequency. Assume unity gain for the receiver antenna. As an engineer working for Sixam, you have been assigned to compute the signal strength at a few different locations from the proposed transmitter.

(i) Express the transmit power in unit of dBm.

(ii) Express the transmit power in unit of dBW.

(iii) Find the received power in dBm at a free space distance of 50m from the antenna.

(iv) Find the received power in dBm at a free space distance of 5km from the antenna.

[3 + 3 + 3 + 3 = 12 marks]

Question 3

(a) With the aid of diagrams, describe the three Kepler's laws of planetary motion.

[9 marks]

(b) Satellite X in orbit has an inclination of 63.45° and circles the Earth once in 23h 56m 4s. Its apogee *altitude* is given as 39,105km and it is visible from the same location on Earth twice a day. The semi major axis for the orbit is given as a = 26,561.734 km.

(i) Determine the type for Satellie X.

[1 mark]

(ii) Calculate the eccentricity e and perigee *altitude*, A_p.

[4 marks]

(iii) Find the mean anomaly of the satellite after 2 minutes the passage of perigee.

[5 marks]

(c) Discuss how satellite orbital altitude affects the transmitter-receiver path loss and the life span of the satellite.

[6 marks]

Continued...

Question 4

(a) Table Q4.1 shows data for a satellite link budget analysis. Calculate the following parameters based on this table.

Table Q4.1

Uplink	
Frequency, f_U	14 GHz
Range	42,000 km
$EIRP_U$	80 dBW
Clear sky atmospheric absorption	0.3 dB
Satellite transponder	
Power flux density at saturation, ϕ_{sat}	-70 dBW/m^2
Power flux density	-83.76dBW/m^2
Directivity of receiving antenna, G_{SRmax}	45 dBi
Receiver feeder loss, $L_{FRX,\,S}$	3 dB
System noise temperature, T	600 K
EIRP at saturation, $EIRP_{sat}$	40 dBW
A_{eff}	1.16m^2
Channel amplifier characteristic:	
OBO	-8.37dB
Downlink	
Frequency, f_D	12 GHz
Clear sky path loss	200 dB
Receiving earth station	
Figure of Merit, $(G/T)_{ES}$	28 dB/K
Receiver feeder loss, $L_{FRX,\,ES}$	3dB

(i) Satellite transponder input back-off, IBO.

[1 mark]

(ii) Saturated carrier power measured at the satellite receiver, $C_{U,\,sat}$

[3 marks]

(iii) Carrier power measured at the satellite receiver, C_U

[1 mark]

(iv) Uplink carrier-to-noise power spectral density, $(C/N_0)_U$

[3 marks]

(v) Downlink carrier-to-noise power spectral density, $(C/N_0)_D$

[2 marks]

(vi) Overall carrier-to-noise power spectral density, $(C/N_0)_T$

[2 marks]

Continued...

(b) The satellite MEASAT 3A which is located at 91.4°E has a satellite transponder utilizing a 252-channel frequency division multiplexed voice system with the details shown in Table Q4.2.

Table Q4.2

RMS deviation of 0 dBm test tone, Δf_{rms}	358 kHz
Multi-channel peak factor, g	3.2
Maximum baseband frequency, f_{max}	1052 kHz
Guard band	10% of the occupied bandwidth
Required Signal-to-Noise power ratio, S/N	60 dB
Pre-/de-emphasis gain, P	3.5 dB
Noise weighing factor, W	3 dB
Voice channel	4 kHz

Calculate the:

(i) Required RF bandwidth.

[5 marks]

(ii) Carrier-to-noise power ratio, C/N.

[4 marks]

(c) State TWO subsystems on board the satellite and describe its functions.

[4 marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^{8} m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.379×10^{-23} J/K = -228.6 dBW/Hz K

Appendix II: Table of Complementary Error Function

$$erfc(z)=\frac{2}{\sqrt{\pi}}\int_{z}^{\infty} e^{-t^2}dt \text{ for } 0\le z\le 3.99 \text{ in steps of } 0.01$$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: 1.000E-01 = 1.000 x 10^{-1}

For $z>4$, $$erfc(z)\approx\frac{1}{\sqrt{\pi}}\left(\frac{e^{-z^2}}{z}\right)$$

Continued...

Appendix III: Erlang B and Erlang C Chart

Erlang B Traffic Table

Maximum Offered Load Versus B and N
B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34
44	24.33	26.53	27.64	30.80	32.54	34.68	38.56	43.09	47.09	51.09	59.92	71.01
45	25.08	27.32	28.45	31.66	33.43	35.61	39.55	44.17	48.25	52.32	61.35	72.67

Continue on the following page.

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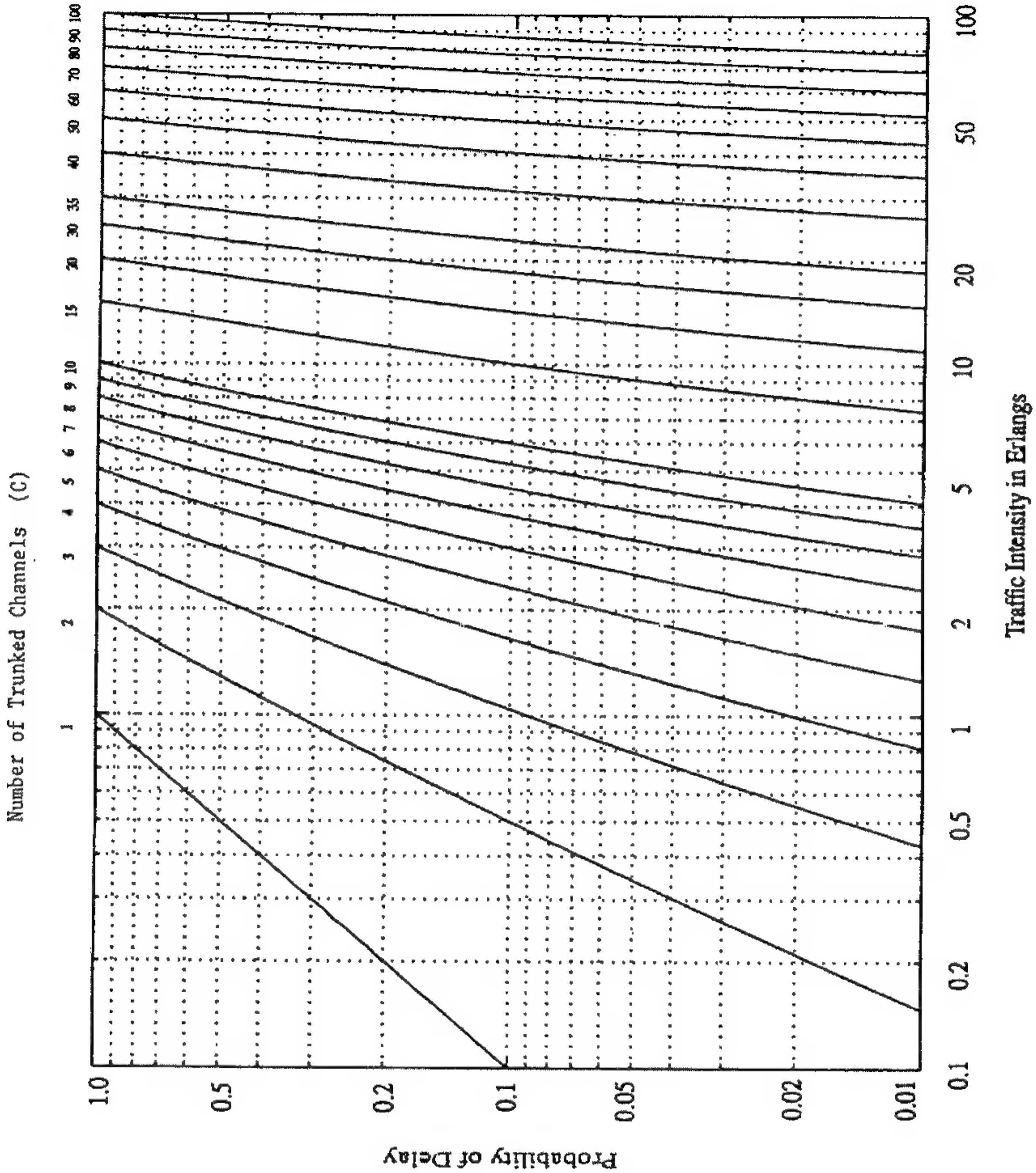
46	25.83	28.11	29.26	32.52	34.32	36.53	40.55	45.24	49.40	53.56	62.77	74.33
47	26.59	28.90	30.07	33.38	35.22	37.46	41.54	46.32	50.56	54.80	64.19	76.00
48	27.34	29.70	30.88	34.25	36.11	38.39	42.54	47.40	51.71	56.03	65.61	77.66
49	28.10	30.49	31.69	35.11	37.00	39.32	43.53	48.48	52.87	57.27	67.04	79.32
50	28.87	31.29	32.51	35.98	37.90	40.26	44.53	49.56	54.03	58.51	68.46	80.99
51	29.63	32.09	33.33	36.85	38.80	41.19	45.53	50.64	55.19	59.75	69.88	82.65
52	30.40	32.90	34.15	37.72	39.70	42.12	46.53	51.73	56.35	60.99	71.31	84.32
53	31.17	33.70	34.98	38.60	40.60	43.06	47.53	52.81	57.50	62.22	72.73	85.98
54	31.94	34.51	35.80	39.47	41.51	44.00	48.54	53.89	58.66	63.46	74.15	87.65
55	32.72	35.32	36.63	40.35	42.41	44.94	49.54	54.98	59.82	64.70	75.58	89.31
56	33.49	36.13	37.46	41.23	43.32	45.88	50.54	56.06	60.98	65.94	77.00	90.97
57	34.27	36.95	38.29	42.11	44.22	46.82	51.55	57.14	62.14	67.18	78.43	92.64
58	35.05	37.76	39.12	42.99	45.13	47.76	52.55	58.23	63.31	68.42	79.85	94.30
59	35.84	38.58	39.96	43.87	46.04	48.70	53.56	59.32	64.47	69.66	81.27	95.97
60	36.62	39.40	40.80	44.76	46.95	49.64	54.57	60.40	65.63	70.90	82.70	97.63
61	37.41	40.22	41.63	45.64	47.86	50.59	55.57	61.49	66.79	72.14	84.12	99.30
62	38.20	41.05	42.47	46.53	48.77	51.53	56.58	62.58	67.95	73.38	85.55	101.0
63	38.99	41.87	43.31	47.42	49.69	52.48	57.59	63.66	69.11	74.63	86.97	102.6
64	39.78	42.70	44.16	48.31	50.60	53.43	58.60	64.75	70.28	75.87	88.40	104.3
65	40.58	43.52	45.00	49.20	51.52	54.38	59.61	65.84	71.44	77.11	89.82	106.0
66	41.38	44.35	45.85	50.09	52.44	55.33	60.62	66.93	72.60	78.35	91.25	107.6
67	42.17	45.18	46.69	50.98	53.35	56.28	61.63	68.02	73.77	79.59	92.67	109.3
68	42.97	46.02	47.54	51.87	54.27	57.23	62.64	69.11	74.93	80.83	94.10	111.0
69	43.77	46.85	48.39	52.77	55.19	58.18	63.65	70.20	76.09	82.08	95.52	112.6
70	44.58	47.68	49.24	53.66	56.11	59.13	64.67	71.29	77.26	83.32	96.95	114.3
71	45.38	48.52	50.09	54.56	57.03	60.08	65.68	72.38	78.42	84.56	98.37	116.0
72	46.19	49.36	50.94	55.46	57.96	61.04	66.69	73.47	79.59	85.80	99.80	117.6
73	47.00	50.20	51.80	56.35	58.88	61.99	67.71	74.56	80.75	87.05	101.2	119.3
74	47.81	51.04	52.65	57.25	59.80	62.95	68.72	75.65	81.92	88.29	102.7	120.9
75	48.62	51.88	53.51	58.15	60.73	63.90	69.74	76.74	83.08	89.53	104.1	122.6
76	49.43	52.72	54.37	59.05	61.65	64.86	70.75	77.83	84.25	90.78	105.5	124.3
77	50.24	53.56	55.23	59.96	62.58	65.81	71.77	78.93	85.41	92.02	106.9	125.9
78	51.05	54.41	56.09	60.86	63.51	66.77	72.79	80.02	86.58	93.26	108.4	127.6
79	51.87	55.25	56.95	61.76	64.43	67.73	73.80	81.11	87.74	94.51	109.8	129.3
80	52.69	56.10	57.81	62.67	65.36	68.69	74.82	82.20	88.91	95.75	111.2	130.9
81	53.51	56.95	58.67	63.57	66.29	69.65	75.84	83.30	90.08	96.99	112.6	132.6
82	54.33	57.80	59.54	64.48	67.22	70.61	76.86	84.39	91.24	98.24	114.1	134.3
83	55.15	58.65	60.40	65.39	68.15	71.57	77.87	85.48	92.41	99.48	115.5	135.9
84	55.97	59.50	61.27	66.29	69.08	72.53	78.89	86.58	93.58	100.7	116.9	137.6
85	56.79	60.35	62.14	67.20	70.02	73.49	79.91	87.67	94.74	102.0	118.3	139.3
86	57.62	61.21	63.00	68.11	70.95	74.45	80.93	88.77	95.91	103.2	119.8	140.9
87	38.44	62.06	63.87	69.02	71.88	75.42	81.95	89.86	97.08	104.5	121.2	142.6
88	59.27	62.92	64.74	69.93	72.82	76.38	82.97	90.96	98.25	105.7	122.6	144.3
89	60.10	63.77	65.61	70.84	73.75	77.34	83.99	92.05	99.41	107.0	124.0	145.9
90	60.92	64.63	66.48	71.76	74.68	78.31	85.01	93.15	100.6	108.2	125.5	147.6
91	61.75	65.49	67.36	72.67	75.62	79.27	86.04	94.24	101.8	109.4	126.9	149.3
92	62.58	66.35	68.23	73.58	76.56	80.24	87.06	95.34	102.9	110.7	128.3	150.9
93	63.42	67.21	69.10	74.50	77.49	81.20	88.08	96.43	104.1	111.9	129.8	152.6
94	64.25	68.07	69.98	75.41	78.43	82.17	89.10	97.53	105.3	113.2	131.2	154.3
95	65.08	68.93	70.85	76.33	79.37	83.13	90.12	98.63	106.4	114.4	132.6	155.9
96	65.92	69.79	71.73	77.24	80.31	84.10	91.15	99.72	107.6	115.7	134.0	157.6
97	66.75	70.65	72.61	78.16	81.25	85.07	92.17	100.8	108.8	116.9	135.5	159.3
98	67.59	71.52	73.48	79.07	82.18	86.04	93.19	101.9	109.9	118.2	136.9	160.9
99	68.43	72.38	74.36	79.99	83.12	87.00	94.22	103.0	111.1	119.4	138.3	162.6
100	69.27	7~.25	75.24	80.91	84.06	87.97	95.24	104.1	112.3	120.6	139.7	164.3

N is the number of servers. The numerical column headings indicate blocking probability B in %. Table generated by Dan Dexter

Continued…



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Continued...

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \dfrac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right) A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{Total}]$

Free space loss,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

$$PL(\text{dB}) = 10\log\left(\frac{P_t}{P_r}\right) = -10\log\left(\frac{\lambda^2}{(4\pi)^2 d^2}\right)$$

$$P_r(d)\,\text{dBm} = 10\log\left[\frac{P_r(d_0)}{0.001\text{ W}}\right] + 20\log\left(\frac{d_0}{d}\right) \qquad d \ge d_0 \ge d_f$$

Log-Distance Path Loss

$$\overline{PL}(\text{dB}) = \overline{PL}(d_0) + 10\,n\log\left(\frac{d}{d_0}\right)$$

Doppler shift,

$$f_d = \frac{v}{\lambda}\cos\theta$$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \dfrac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \dots + \frac{T_{en}}{G_1 G_2 \dots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$

$$\text{where } \log_{10} l = \begin{cases} (-1 + 4\log_{10} n)/20, & n \le 240 \\ (-15 + 10\log_{10} n)/20, & n > 240 \end{cases}$$

Relationship between C/N and S/N is given by:

$$\frac{C}{N} = \left(\frac{S}{N}\right)\left(\frac{b}{B}\right)\left(\frac{f_{\max}}{\Delta f_{rms}}\right)^2 \frac{1}{pw}$$

End of Paper